

## PART I - ADMINISTRATIVE

### Section 1. General administrative information

Title of project

Physiological Assessment of wild and hatchery juvenile salmonids.

BPA project number	9202200
--------------------	---------

Contract renewal date (mm/yyyy)	06/2000
------------------------------------	---------

Multiple actions? (indicate Yes or No)	No
---	----

Business name of agency, institution or organization requesting funding

National Marine Fisheries Service, NOAA, DOC

Business acronym (if appropriate)	NMFS
-----------------------------------	------

Proposal contact person or principal investigator:

Name	Walton Dickhoff
Mailing address	2725 Montlake Blvd. East
City, ST Zip	Seattle, WA 98112-2097
Phone	202-860-3234
Fax	206-860-3267
Email address	walton.w.dickhoff@noaa.gov

NPFC Program Measure Number(s) which this project addresses

Measure 7.2D1,3,5; 7.4K1; 8.3c

FWS/NMFS Biological Opinion Number(s) which this project addresses

All BiOps

Other planning document references

Snake River Recovery Plan Tasks 4.3 and 4.4

Short description

The overall goal of this research is to reduce negative impact of hatchery salmon on wild salmon and evaluate supplementation by 1) improving the smolt quality and smolt-to-adult survival of fish reared in hatcheries, and 2) producing a more wild-type hatchery smolt in supplementation programs. The experimental objectives of our on-going and proposed work include improving smolt-to-adult survival of the Columbia River terminal fishery

(CCEDC, ODFW, WDFW) by growth rate manipulation (winter dormancy and enhancing spring growth rate) of juvenile spring chinook salmon before release. A second major element of our research is to characterize the physiology of salmon reared under conventional and natural-rearing systems in the supplementation program at the Cle Elum Hatchery (Yakama Indian Nation and WDFW). Finally, we propose to compare the physiology of hatchery reared fish at the Cle Elum Hatchery to that of naturally rearing fish during outmigration.

---

**Target species**

---

Spring chinook salmon (*Oncorhynchus tshawytscha*)

---

## Section 2. Sorting and evaluation

**Subbasin**

---

Ocean/estuary, Yakima

---

### *Evaluation Process Sort*

CBFWA caucus		CBFWA eval. process		ISRP project type	
X one or more caucus		If your project fits either of these processes, X one or both		X one or more categories	
X	Anadromous fish		Multi-year (milestone-based evaluation)		Watershed councils/model watersheds
	Resident Fish		Watershed project eval.		Information dissemination
	Wildlife				Operation & maintenance
					New construction
				X	Research & monitoring
					Implementation & mgmt
					Wildlife habitat acquisitions

## Section 3. Relationships to other Bonneville projects

***Umbrella / sub-proposal relationships.*** List umbrella project first.

Project #	Project title/description

***Other dependent or critically-related projects***

Project #	Project title/description	Nature of relationship
9306000	Columbia River Terminal Fisheries Research Project	Laboratory analysis of physiology samples and analysis and interpretation of tag return data
9506300	Yakima/Klickitat Monitoring & Evaluation Program	Monitor physiology of supplementation fish at Cle Elum Hatchery
9506406	Monitoring of supplementation response variable for YKFP	Monitor physiology of captured fish released from Cle Elum Hatchery and wild fish during outmigration

**Section 4. Objectives, tasks and schedules**

***Past accomplishments***

Year	Accomplishment	Met biological objectives
1994-5	Monitored physiology of wild salmon juveniles	
1996	Demonstrated effects of growth regulation on juvenile	

	salmon	
1997	Completed wild fish analysis	
1998	Published 3 papers in peer-reviewed literature on work described above.	

### ***Objectives and tasks***

Obj 1,2 ,3	Objective	Task a,b, c	Task
1.	Manipulate growth rates of spring chinook salmon to correspond to pattern seen in wild fish.	a.	Analyze samples and data on physiology of juvenile salmon
		b	Compare smolt-to-adult survival of experimental groups and publish results.
2.	Evaluate physiology of juvenile spring chinook salmon in supplementation program.	a	Sample fish, analyze data on physiology of juvenile salmon
		b	Compare results with physiology of wild spring chinook salmon juveniles
3.	Evaluate physiology of hatchery and wild spring chinook migrants	a	Sample fish, analyze data on physiology of juvenile salmon

### ***Objective schedules and costs***

Obj #	Start date mm/yyyy	End date mm/yyyy	Measureable biological objective(s)	Milestone	FY20 Cost
1	06/2000	05/2006	Improve smolt-to-adult survival	Establish fish husbandry procedure - publish results	
2	06/2000	05/2001	Characterize physiology	Establish fish husbandry	

				procedure - publish results	
3	06/2000	05/2008	Characterize physiology	Establish fish husbandry procedure - publish results	
				<b>Total</b>	<b>1</b>

**Schedule constraints**

None anticipated

**Completion date**

May 2008

## Section 5. Budget

**FY99 project budget (BPA obligated):** | \$349,000

***FY2000 budget by line item***

Item	Note	% of total 1	FY2000 (
Personnel		21	73,462
Fringe benefits		4	13,273
Supplies, materials, non- expendable property		4	16,102
Operations & maintenance		2	5,411
Capital acquisitions or		0	0

9202200 Physiological Assessment of wild and hatchery juvenile salmonids.

improvements (e.g. land, buildings, major equip.)			
NEPA costs		0	0
Construction-related support		0	0
PIT tags	# of tags:	0	0
Travel		2	6,432
Indirect costs		18	65,384
Subcontractor		50	178,000
Other		0	0
<b>TOTAL BPA REQUESTED BUDGET</b>			<b>358,0</b>

### ***Cost sharing***

Organization	Item or service provided	% total project cost (incl. BPA)	Amount (
<b>Total project cost (including BPA portion)</b>			

### ***Outyear costs***

	FY2001	FY02	FY03	FY
<b>Total budget</b>	<b>359,000</b>	<b>360,000</b>	<b>363,000</b>	<b>365,000</b>

## **Section 6. References**

Watershed ?	Reference
	Beckman, B.R., W.W. Dickhoff, W.S. Zaugg, C. Sharpe, S. Hirtzel, R. Schrock, D.A. Larsen, R.D. Ewing, A. Palmisano, C.B. Schreck, C.V.W. Mahnken. 1999. Growth, smoltification, and smolt-to-adult return of spring chinook salmon ( <i>Oncorhynchus tshawytscha</i> ) from hatcheries on the Deschutes River, Oregon. Transactions of the American Fisheries Society (accepted).
	<b>Beckman, B.R., D.A. Larsen, B. Lee-Pawlak, and W.W.</b>

	Dickhoff. 1996. Physiological assessment and behavior interaction of wild and hatchery juvenile salmonids: The relationship of fish size and growth to smoltification in spring chinook salmon. Annual report to the Bonneville Power Administration Project 92-022. October 1996.
	Dickhoff, W.W., B.R. Beckman, D.A. Larsen, C.V.W. Mahnken, C.B. Schreck and W.S. Zaugg. 1995. Smolt quality assessment of hatchery-reared spring chinook salmon in the Columbia River basin. AFS symposium, 15:292-302.
	Dickhoff, W.W., B.R. Beckman, D.A. Larsen and B. Lee-Pawlak. 1997. Physiology of migration in salmonids. Mem. Fac. Fish. Hokkaido Univ. 44:14-16.
	Dickhoff, W.W., Beckman, B.R., Larsen, D.A., Duan, C. and Moriyama, S. 1997. The role of growth in endocrine regulation of salmon smoltification. Fish Physio. Biochem. 17:231-236.
	Hoar, W.S. 1988. The physiology of smolting salmonids. In: W.S. Hoar and D.J. Randall eds., Fish Physiology Vol. 11B. Academic Press, New York. pp. 275-344.
	Moriyama, S., P. Swanson, M. Nishii, A. Takahashi, H. Kawauchi, W.W. Dickhoff and E.M. Plisetskaya. 1994. Development of a homologous radioimmunoassay for coho salmon insulin-like growth factor-I. Gen. Comp. Endocrinol. 96:149-161.
	RASP. 1992. Supplementation in the Columbia Basin, Summary Report Series, Final Report. Bonneville Power Administration, Project number 85-62.
	Sakamoto, T. and T. Hirano. 1993. Expression of insulin-like growth factor I gene in osmoregulatory organs during seawater adaptation of the salmonid fish: Possible mode of osmoregulatory action of growth hormone. Proc. Natl. Acad. Sci. USA 90:1912-1916.
	Varnavskiy, V.S., N.V. Varnavskay, S.V. S. Kalinin, and N.M. Kinas. 1992. RNA/DNA index as an indicator of growth rate of coho salmon ( <i>Oncorhynchus kisutch</i> ) during early marine life. J. Ichthyol. 32:10-19.
	Wagner, H.H., F.P. Conte, and J.L. Fessler. 1969. Development of osmotic and ionic regulation in two races of chinook salmon <i>Oncorhynchus tshawytscha</i> . Comp. Biochem. Physiol. 29:325-341.
	Zaugg, W.S., W.W. Dickhoff, B.R. Beckman, C.V.W. Mahnken, G.A. Winans, T.W. Newcomb, C.B. Schreck, A.M. Palmisano, B.M. Schrock, G.A. Wedemeyer, R.D. Ewing,

	and C.W. Hopley. 1991. Smolt quality assessment of spring chinook salmon. Bonneville Power Administration Project No. 89-046, Annual report, 109 p.

## PART II - NARRATIVE

### Section 7. Abstract

Our goal is to reduce negative impacts of hatchery on wild salmon and evaluate supplementation by 1) improving smolt quality and smolt-to-adult survival (SAS) of fish reared in hatcheries, and 2) producing a more wild-type hatchery smolt in supplementation programs. Items addressed in the 1995 FWP include 7.2D1,3,5; 7.3B.2,6,7, 7.4K.1; 8.3c. High smolt quality is defined operationally as fish that migrate rapidly after release and survive to adulthood at relatively high rates. Rapid downstream movement after release reduces hatchery fish interaction and competition with wild fish. Fish that migrate rapidly downstream will not residualize and imprint on stream sites adjacent to the hatchery, which means less straying of adults during homing and less breeding and genetic introgression with wild fish. Improving SAS of hatchery production fish will allow reduced numbers of juveniles released to realize the same number of adults contributed, and reduce impacts of hatchery on wild fish. Our previous research found correlations between smolt quality indices, spring growth, and SAS of spring chinook salmon in production hatcheries. Furthermore, accelerating spring growth improved instream migration of smolts. We also characterized the physiology of wild chinook salmon in the Yakima River. Proposed experimental objectives include 1) improving SAS of Columbia River terminal fishery by growth rate manipulation of juveniles, 2) evaluate the physiology of salmon reared under conventional and natural-rearing systems in the supplementation program of the Cle Elum Hatchery (Yakama Indian Nation and WDFW), 3) compare the physiology of the Cle Elum Hatchery fish with that of naturally rearing Yakima River fish during outmigration. The outcome will be new rearing protocols for improving SAS and producing wild like salmon smolts in hatcheries. Results will be published in the peer-reviewed literature.



## **Section 8. Project description**

### **a. Technical and/or scientific background**

PROBLEM: It is perceived that hatchery-reared salmonids are of inferior quality and have lower smolt-to-adult survival compared to naturally-reared salmon. Our research has shown that smolt quality of hatchery fish differs from that of wild fish in at least four aspects: size, growth rate, body fat, and dynamic physiological changes associated with smoltification. Our recent studies suggest that high growth rate during smolting stimulates downstream migration, but the impact of high growth rate on smolt-to-adult survival of hatchery-reared fish remains to be demonstrated. Although data are available on the physiology of wild spring chinook salmon juveniles, it is not clear that wild-like fish can be produced in captivity or whether hatchery production of wild-like fish would improve smolt-to-adult survival. In supplementation programs, it is critical that smolts are produced that have wild-like physiological attributes, yet the methods to produce wild-like smolts have not been established.

The objective of our research is to manipulate growth rates of hatchery reared fish to improve smolt quality, produce a more wild-type hatchery smolt, and accomplish the following goals:

- 1) Improve smolt-to-adult survival
- 2) Reduce interactions between wild and hatchery juveniles
- 3) Allow for the design of effective rearing programs for producing wild-like smolts in supplementation projects
- 4) Reduce straying and genetic introgression of hatchery fish on protected salmonid populations

This proposal addresses the Northwest Power Planning Council plan to "minimize genetic and ecological impacts of hatchery fish on wild stocks" as described in Phase One Amendments (Measure 2.4 ) to the Columbia River Basin Fish and Wildlife Program (adopted 14 August 1991). The major emphasis of this work will concentrate on assessing whether characteristics of smoltification and downstream migration of wild fish can be reproduced and applied to hatchery-reared fish. The proposal also addresses the NMFS Proposed Recovery Plan for Snake River Salmon (March 1995) Task 4.4 "Improve survival of Columbia River Basin anadromous salmonids by improving quality of fish released from hatcheries" and the goal to "Minimize impacts on listed salmon from interactions between Columbia River Basin hatchery salmon and natural salmon" (Task 4.3). The proposal also addresses FWP (1995) objectives to maximize post-release survival of hatchery fish (Section 7.2D1,3,5), evaluate supplementation programs (Section 7.3B.2,6,7)

including the Yakama program (Section 7.4K.1), and assist the development of terminal harvest fisheries (Section 8.3C).

Our studies on the quality of juvenile salmon produced by Columbia River hatcheries have indicated significant variation in timing and degree of smolt development among hatcheries. Most significantly, we found that differences in smolt development were positively correlated with smolt-to-adult survival (Dickhoff et al., 1995, Beckman et al., 1999). These differences in smolt development and their relation to adult survival have implications regarding fish-rearing procedures and management of hatchery releases. One of the most significant findings of our studies of hatchery-reared chinook salmon is the positive relation between growth rate during the two months immediately preceding release and survival to adulthood. Furthermore, we have shown that increasing spring growth rate by experimental manipulation of spring chinook salmon improves their downstream movement (Beckman et al., 1996). This work suggests that accelerating growth rate of hatchery fish just prior to release may improve smolt quality and enhance downstream migration.

The linkage between growth rate, smoltification, seawater tolerance and migration rate has been observed previously (Wagner et al. 1969; Varnavsky et al. 1992). Furthermore, it is compelling that such a link should exist, since the same hormones that control growth rate (growth hormone, insulin-like growth factor-I) also stimulate the development of seawater tolerance in salmonids (see Sakamoto and Hirano 1993 for review). Enhanced seawater tolerance is a characteristic attribute of successful smoltification (Hoar 1988).

In addition to our studies of hatchery salmon, we have studied wild juvenile spring chinook salmon in the Yakima River Basin. One of the rationales for the study of wild salmonids is that their physiology may serve as a template for improving hatchery rearing of salmon in production or supplementation programs. A better understanding of the physiology of wild fish should enable us to produce more wild-like fish in hatcheries. There are perceived differences in performance (migrational and smolt-to-adult survival) between wild/natural and hatchery-produced spring chinook salmon smolts, especially in the mid-and upper Columbia and Snake Rivers. Survival of hatchery smolts is generally lower than that of wild fish and hatcheries often have difficulty in procuring enough adults for brood stock.

Furthermore, it is critical to produce smolts with physiological attributes of wild fish in supplementation programs (RASP 1992).

Results on wild spring chinook salmon juveniles indicate a dynamic pattern of physiological development (Dickhoff et al. 1997). In late autumn and early winter the wild fish reduce growth rate, feeding activity and metabolism. Wild

fish lose substantial amounts of body fat over the winter in sharp contrast to hatchery reared salmon, which are generally obese (three to five times fatter than wild fish).

In late winter and early spring, wild yearlings dramatically increase feeding, accumulate body fat, and resume growth. The sharp increase in growth of wild fish concomitant with smoltification is similar to the rapid growth of high quality smolts in hatcheries in our previous studies. In summary, we can list several major differences in wild spring chinook salmon smolts compared to hatchery smolts:

- 1) Wild smolts are generally smaller than hatchery smolts of equivalent smolt-to-adult survival.
- 2) Wild fish show rapid growth rate (as assessed by plasma insulin-like growth factor I (IGF-I) level) during the smolting period.
- 3) Wild smolts have less body fat than hatchery smolts.
- 4) Wild smolts show a more dynamic change in physiological and metabolic status from overwintering to the spring smolting period.

In production-scale studies at Youngs Bay, OR we are testing the hypothesis that dynamic changes in growth and metabolism of juvenile salmon during winter/spring promote smoltification, improve the quality of hatchery-reared smolts, and improve smolt-to-adult returns. Furthermore, we are monitoring the physiology of fish reared under conventional and natural rearing systems in the supplementation program of the Cle Elum Hatchery and comparing it to the physiological template constructed from wild Yakima River chinook salmon. Finally, we will monitor and compare the physiology of both hatchery and wild fish during outmigration through Roza dam, the Chandler by-pass facility and McNary Dam.

## **b. Rationale and significance to Regional Programs**

The rationale of our studies is that methods of rearing spring chinook salmon in hatcheries may be modified or manipulated in order to promote physiological development and behavior similar to that found in wild fish. These modifications may result in improved performance characteristics for hatchery fish while minimizing impacts of hatchery fish on wild fish. The results will apply to both production and supplementation hatcheries. A large number of supplementation hatcheries have begun operating within the Columbia River Basin. Our proposed work in the Yakima Fisheries Project will continue to characterize the physiological development of the second year-class of supplementation fish to be reared and released. This will allow for comparisons between year classes, OCT versus SNT reared fish, and wild fish. This is a unique opportunity for research, since we have the largest and most

comprehensive database on the physiological development of juvenile salmon in hatcheries and in the wild. Our physiological data can be used to assess pre-release success and to monitor post-release success in achieving the target of producing a wild-like supplementation smolt. This information can be used to refine rearing protocols to improve post-release performance.

### **c. Relationships to other projects**

1. The proposed collaborative work with the Columbia River terminal fishery project in Youngs Bay OR (BPA project #9306000) is an opportunity for us to perform production-scale tests of our hypotheses on improving smolt quality by growth rate manipulation and patterning wild smolt development. The terminal fisheries project is a collaboration between Clatsop County Economic Development Council, and the Oregon and Washington Departments of Fish and Wildlife. Their on-going studies examine the time of release and smolt-to-adult recovery (SAR) of spring chinook salmon juveniles. Our proposal will examine the quality of smolts released and modify growth rates of fish to improve efficiency and SAR. This terminal fishery has a high rate of adult return relative to upper river production programs.

Thus, comparisons of SAR of experimental groups will be statistically robust. There is a substantial economy in research costs because of such a collaborative and mutually beneficial effort. The results of the proposed studies on rearing protocols can be expanded to include all spring chinook production hatcheries in the Columbia River Basin. Recently WDFW has requested our input on rearing protocols for their production and supplementation hatcheries.

2. The continued evaluation of spring chinook salmon in the supplementation project in Yakima River Basin (BPA projects #956300 and 9506406) is a collaboration with the Washington Department of Fish and Wildlife and the Yakama Indian Nation. The proposed research is a logical next step to our previous work characterizing the physiology of wild spring chinook salmon in the Yakima River. This collaborative effort will provide the most complete evaluation of supplementation efforts available. The results should be applicable to all supplementation programs in the Columbia River Basin.

3. The proposed evaluation of outmigrating hatchery chinook salmon from the supplementation project in the Yakima River Basin (BPA projects #956300 and 9506406) and naturally rearing fish is a collaboration with the WDFW and the YIN. This research is an essential first step in understanding the physiological attributes of the most successful hatchery

and naturally rearing smolts (i.e. those that have survived to migrate from the basin). The results should provide information which is applicable to all supplementation programs in the Columbia River Basin.

**d. Project history** (for ongoing projects)

Project # 9202200. The project began in 1992 with selection of collection sites in the Yakima River Basin and standardization of collection methods. Wild fish sampling began in 1993 and continued through 1995. Sample and data analysis of wild fish samples began in 1994 and continued through 1997. In 1998 a collaborative project with WDFW and YIN began, collecting samples from the first generation of OCT and SNT hatchery fish reared at the Cle Elum Supplementation hatchery. Studies testing growth manipulation and the relationship between high spring growth rate and smolt-to-adult survival in the Youngs Bay Terminal Fishery were initiated in 1997 with sample collection scheduled through 1999.

Major results achieved include:

1. Characterization of physiology of wild spring chinook salmon, which differ significantly from hatchery reared fish.
2. Demonstration of the relationship between high growth rate, smoltification and downstream migration.

**Publications:**

- Dickhoff, W.W., B.R. Beckman, D.A. Larsen, C.V.W. Mahnken, C.B. Schreck and W.S. Zaugg. 1995. Smolt quality assessment of hatchery-reared spring chinook salmon in the Columbia River basin. AFS symposium, 15:292-302.
- Beckman, B.R., D.A. Larsen, B. Lee-Pawlak, and W.W. Dickhoff. 1996. Physiological assessment and behavior interaction of wild and hatchery juvenile salmonids: The relationship of fish size and growth to smoltification in spring chinook salmon. Annual report to the Bonneville Power Administration Project 92-022. October 1996.
- Dickhoff, W.W., B.R. Beckman, D.A. Larsen, C. Duan and S. Moriyama. 1997. The role of growth in the endocrine regulation of salmon smoltification. Fish Physiol. Biochem. 17:231-236.
- Dickhoff, W.W., B.R. Beckman, D.A. Larsen and B. Lee-Pawlak. 1997. Physiology of migration in salmonids. Mem. Fac. Fish. Hokkaido Univ. 44:14-16.
- Beckman, B.R., D.A. Larsen, S. Moriyama, B. Lee-Pawlak and W.W. Dickhoff. 1998. Environmental modulation of the growth hormone-insulin-like factor-I endocrine axis and its relation to size, growth and smoltification in juvenile spring chinook salmon (*Oncorhynchus tshawytscha*). Gen. Comp. Endocrinol. 109, 325-335.

Beckman, B.R., D.A. Larsen, B. Lee-Pawlak and W.W. Dickhoff. 1998. The relationship of fish size and growth rate to migration of spring chinook salmon (*Oncorhynchus tshawytscha*) smolts. North American Journal of Fisheries Management 18:537-546.

Beckman, B.R. and W.W. Dickhoff. 1998. Plasticity of smoltification in spring chinook salmon (*Oncorhynchus tshawytscha*): Relation to growth and insulin-like growth factor-I. J. Fish Biology 53: 808-826.

Beckman, B.R., W.W. Dickhoff, W.S. Zaugg, C. Sharpe, S. Hirtzel, R. Schrock, D.A. Larsen, R.D. Ewing, A. Palmisano, C.B. Schreck, C.V.W. Mahnken. 1999. Growth, smoltification, and smolt-to-adult return of spring chinook salmon (*Oncorhynchus tshawytscha*) from hatcheries on the Deschutes River, Oregon. Transactions of the American Fisheries Society (accepted).

Years underway: 6

Past costs: \$1,752,150

#### **e. Proposal objectives**

1. Manipulate growth rates of spring chinook salmon to correspond to patterns seen in wild fish. Determine whether winter dormancy and high growth rate during smolting improves smolt-to-adult survival of spring chinook salmon released from net pens in the Columbia River terminal fisheries project (BPA project #9306000).

The hypothesis is: Growth patterns of wild fish can be reproduced on a hatchery production scale and will improve smolt-to-adult survival. Products from this study will include BPA reports and peer-reviewed publications. The work is being done at a production facility, so technology transfer is assured.

2. Evaluate rearing protocols and monitor smolt quality of spring chinook salmon juveniles in the optimal conventional treatment (OCT) and semi-natural treatment (SNT) rearing systems in the Cle Elum supplementation hatchery program (BPA projects # 956300 and 9506406). The hypothesis to be tested is: hatchery-reared fish raised using OCT and/or SNT rearing protocols have similar physiological and morphological profiles to that of naturally rearing fish. The objective will be to evaluate the quality of smolts in the supplementation program by their physiological attributes, and compare the data with that which was collected previously for wild and hatchery fish. Results will be published as BPA reports and in the peer-reviewed literature. Technology transfer will be assured since we will be working with the hatchery manager.

3. Monitor the physiology of outmigrating smolts produced

under the OCT and SNT rearing systems in the Cle Elum supplementation hatchery program as well as naturally rearing smolts. The hypothesis to be tested is: hatchery-reared fish raised according to OCT and/or SNT rearing systems in the Cle Elum supplementation hatchery will have similar physiological, morphological, and behavioral attributes to outmigrating naturally reared fish. The objective is to collect physiological samples from tagged outmigrating hatchery fish and wild fish as they pass through Roza Dam, the Chandler bypass facility and McNary Dam. Results will be published as BPA reports and in the peer-reviewed literature. Technology transfer will be assured since we will be working directly with WDFW and YIN biologists throughout the study.

#### **f. Methods**

A project is proposed with the following goals: 1) analyze samples and analyze and interpret tag return data from an experiment manipulating growth rates of spring chinook salmon in the Columbia River terminal fishery project in Youngs Bay OR (BPA project #9306000), 2) evaluate physiology of spring chinook salmon in supplementation project in Yakima River Basin (BPA projects #956300 and 9506406), 3) evaluate physiology of supplementation hatchery and wild spring chinook salmon in the Yakima River Basin during outmigration (BPA projects #956300 and 9506406).

Element 1. Manipulate growth to improve smolt development of spring chinook salmon in the Columbia River terminal fishery.

Experiments will be completed testing the hypothesis that winter dormancy followed by accelerated spring growth rate will improve smolt quality and smolt to adult survival on a production scale.

Spring chinook salmon from Gnat Creek Hatchery, were marked with coded wire tags (CWT) and placed in net pens in Youngs Bay, OR. Fish were fed rations of Biodiet (Bioproducts, Warrenton OR) either on a standard schedule or a restricted schedule to reduce winter growth. The standard ration was according to the feed manufacturer's recommendation adjusted for water temperature. Fish were fasted from December 1 to mid-January (winter dormancy). Maintenance rations of approximately 0.3% body weight per day were fed from mid-January to mid-February. Accelerated growth of the fish on the wild fish growth profile were accomplished by increasing the ration in mid-February to 1 to 2% body weight per day, depending on results obtained from the 1996-7 study. Control fish will be fed on standard rations (Bioproducts recommendation) from November to the

release date of April 1 to achieve the target release size (40g).

Sampling protocol Fifteen fish from each group on each sampling date will be killed to determine seasonal changes in selected physiological variables. Fish will be weighed and measured, and blood will be collected. Coloration will be noted on a three-point scale (1 = parr, 2 = transitional, 3 = smolt). General health (presence or absence of lesions), sex, and gonadal development will be noted. Blood samples will be used to determine hematocrit; the separated plasma fraction will be used to determine insulin-like growth factor-I and insulin levels (volume permitting). Gill tissues will be collected for determination of  $\text{Na}^+\text{-K}^+$  ATPase activity. Remaining fish carcasses will be utilized for determining total body lipid. Fish will be sampled once in February and twice in March to determine seawater tolerance and preference at Oregon State University, using the behavioral chamber that has been developed in Corvallis, OR.

Sample analysis Samples will be analyzed for ATPase activities as described in Zaugg et al. (1991) and for plasma IGF-I as described in Moriyama et al. (1995), and results will be compared to known patterns of change in laboratory and hatchery-reared chinook salmon. Adult survival of released fish will be determined by CWT returns.

It is anticipated that slow growth of fish in winter coupled with accelerated growth of fish in spring will improve smolt quality and smolt-to-adult survival. Graduate students and technicians from the University of Washington will assist in sample collection and analyses.

Anticipated results: We anticipate that physiological development of fish reared on the wild fish growth pattern should show equal or better performance than the control group based on adult return rates. Critical uncertainty revolves around the best method to impose the winter dormancy and accelerated spring growth. How long should the fish be fasted? When should the refeeding period begin? Should the fish be given a maintenance diet during the winter? Is body fat and general health a good index to determine whether the fasting period has compromised fitness or produced chronic stress?

Element 2: Conduct a second year of monitoring of smolt quality of spring chinook salmon juveniles in the optimal conventional treatment (OCT) and semi-natural treatment (SNT) rearing systems in the Cle Elum Supplementation hatchery program. Beginning in August 1999 we will sample 24 fish (8 fish from each of 3 replicate raceways) from the two treatment groups. We will assess smolt morphology, whole body fat level, blood plasma levels of growth regulatory hormones (IGF-I, growth hormone and insulin, volume permitting) and gill  $\text{Na-K}$  ATPase activity. Samples will be collected bi-monthly from August to November (to monitor for Fall smolting), monthly in December and January



and bi-monthly again from February to May. In the Spring of 1999, the fish reared at Cle Elum will be moved to each of three remote acclimation sites in the upper basin. Physiology samples will be collected until the end of the outmigration period at the acclimation sites containing fish from the raceways which were originally sampled at the Cle Elum hatchery.

Expected results: We anticipate that we will find differences in the physiology of fish reared in the OCT and SNT rearing treatments and in comparison with the patterns that we observe in wild spring chinook salmon juveniles in the Yakima River. The different physiological patterns will be used to modify or fine tune rearing protocols in subsequent years.

Element 3: In order to compare the physiology of hatchery fish with wild fish, samples of 10-15 fish per treatment will be collected throughout the outmigration period (April and May) from previously pit-tagged OCT and SNT fish as well as wild fish as they pass through Roza Dam, a series of screw traps operated by the YIN below Roza dam, at the Chandler bypass facility, and at McNary Dam (fish numbers permitting).

Expected results: We anticipate that we will find similar physiological attributes of the successfully outmigrating hatchery reared fish and wild fish during. The changes associated with whole body lipid stores and metabolic hormones during outmigration between hatchery and wild fish may provide significant information regarding energetic balance during this period. These result will be used to modify rearing protocols to optimally prepare subsequent generations of hatchery fish for successful migration.

## **g. Facilities and equipment**

Laboratory and data analyses and base of operations is the Northwest Fisheries Science Center of the National Marine Fisheries Service in Seattle, which is well-equipped to conduct the proposed studies. We have analytical balances, centrifuges, a gamma counter, ELISA plate readers, spectrophotometers, and chemical and radiation safety hoods.

Modern fish rearing facilities available include a computer-operated closed recirculation system with biofiltration, ozonation and UV-radiation to maintain water quality. No additional equipment is requested. We have a van that is equipped with sampling gear, centrifuges and electric generator for field sampling at Youngs Bay terminal fisheries project and at the Cle Elum hatchery.

## **h. Budget**

Salary support is requested for D.A. Larsen and B.R. Beckman who will oversee technical aspects of the project and provide information critical for University of Washington technicians and graduate students who will assist in the project. Mr. Brad Gadberry, Fish Biologist with the UW, will oversee sampling fish at the Youngs Bay facility and participate in fish body fat analysis. Ms. Kathy Cooper, Fish Biologist with the UW, will be responsible for sample analyses for blood plasma hormone concentration and gill ATPase. Graduate students Andy Pierce and Dianne Baker will assist in sample analysis.

Dr. Carl Schreck of the Oregon Cooperative Fishery Research Unit at Oregon State University will oversee OSU participation in fish sampling and data analysis.

## **Section 9. Key personnel**

Dr. Walton W. Dickhoff, Principal Investigator, will oversee progress on the project and be the primary manager of Objective 1. Approximately 30% time will be devoted to this project (supported by NMFS). He has worked on the physiology of salmon smoltification for over 20 years and is internationally recognized in this field.

Dr. Donald A. Larsen (Fishery biologist) is a co-Principal Investigator and primary project manager for Objectives 2 and 3.. He will devote 100% time to the project. He has participated in the research on smolt quality for 9 years.

Mr. Brian R. Beckman (Fishery biologist) is a co-Principal Investigator. He will devote 100% time to the project. He has worked on smolt quality research for over 13 years, and has led the studies of wild smolt physiology.

Biographies:

Walton W. Dickhoff

Education

A.B. Biological Sciences, 1970, University of California, Berkeley.

Ph.D. Physiology, 1976, University of California, Berkeley.

Honors/Awards

U.S. Public Health Service Trainee, 1970-1974.

National Institutes of Health Fellowship, 1976-1977.

Tashiro Fellowship, Kitasato University, Japan, 1987.

Research Faculty Fellowship, Univ. Washington, College of Ocean and Fishery Sciences, 1988.

Distinguished Research Award, Univ. Washington, College of Ocean and Fishery Sciences, 1991.

Employment

1993-1998                      Director, Cooperative Education and Research Program (UW/NMFS)

1987-1998                      Professor (WOT), School of Fisheries, University of Washington.

1982-98                        Physiologist, National Marine Fisheries Service, Northwest Fisheries Research Center, Seattle.

1988-1989                      Assistant Director, Aquaculture Division, School of Fisheries, UW.

1984-1987                      Research Associate, School of Fisheries, University of Washington.

1981, '82, '86                Lecturer, Dept. Zoology, University of Washington.

1977, '79, '80, '82                                      Acting Assistant Professor, Dept. Zoology, University of Washington.

1975-1984                      Research Associate, Dept. Zoology, University of Washington.

1974-1975                      Research Assistant, Dept. Physiology/Anatomy,  
University of California, Berkeley.

### Professional Activities

#### Professional Memberships:

American Association for the Advancement of Science, Society of Integrative and Comparative Biology (former American Society of Zoologists; Chair, Division of Comparative Endocrinology 1993-96), Endocrine Society

#### Editorships:

Member of Editorial Board of General and Comparative Endocrinology 1978-1991.

Acting Editor-in-Chief of General and Comparative Endocrinology in 1979-84.

#### Selected publications:

Dickhoff, W.W., B.R. Beckman, D.A. Larsen, C. Duan and S. Moriyama. 1997. The role of growth in the endocrine regulation of salmon smoltification. *Fish Physiol. Biochem.* 17:231-236.

Dickhoff, W.W., Beckman, B.R., Larsen, D.A., and Lee-Pawlak, B. (1997). Physiology of migration in salmonids. *Mem. Fac. Fish. Hokkaido Univ.* 44, 14-17.

Dickhoff, W.W., Beckman, B. R., Larsen, D. A., Mahnken, C. V. W., Schreck, C. B., Sharpe, C, and Zaugg, W. S. (1995). Quality assessment of hatchery-reared spring chinook salmon smolts in the Columbia River Basin. 292-302. *In* H. L. Schramm and R. G. Piper ed. *Uses and Effects of Cultured Fishes in Aquatic Ecosystems*. Bethesda, Maryland, American Fisheries Society.

Dickhoff, W.W. 1993. Hormones, Metamorphosis and Smolting. *In*: *The Endocrinology of Growth, Development, and Metabolism in Vertebrates*. M.P. Schreibman, C.G Scanes, and P.K.T. Pang, eds. Academic Press, Inc., San Diego, CA pp. 519-540.

Dickhoff, W.W., C.V.W. Mahnken, F.W. Waknitz, W.S. Zaugg, M.G. Bernard and C.V. Sullivan. 1989. Effect of temperature and feeding on smolting and seawater survival of Atlantic salmon (*Salmo salar*). Aquaculture 82:93-102.

Folmar, L. C. and W.W. Dickhoff. 1980. The parr-smolt transformation (smoltification) and seawater adaptation in salmonids. A review of selected literature. Aquaculture 21:1-37.

Donald A. Larsen

## EDUCATION

B.A., Biology, University of Colorado, Boulder, CO. 1986.

M.S., Biology, Western Washington University, Bellingham, WA. 1990.

Ph.D., Fisheries, University of Washington, Seattle, WA.  
1997.

## PROFESSIONAL EXPERIENCE

3/92-Present                      Fisheries Biologist GS-11, Integrative  
Fish Biology Program,                      Resource Enhancement  
and Utilization Technologies Division,  
Northwest Fisheries Science Center, Seattle, WA.

5/90-3/92                      Biological Technician GS-7 (Fisheries),  
Integrative Fish Biology                      Program, Coastal  
Zone and Estuary Studies Division,  
                 Northwest Fisheries Science Center, Seattle, WA.

3/90-5/90 Biological Technician (Fisheries): Foreign  
and Domestic Fisheries Observer Program,  
Resource Ecology and Fisheries Management  
Division, National Marine Fisheries Service, Seattle, WA.

3/88-12/89      Teaching Assistant, Biology Department,  
Western Washington      University,  
Bellingham, WA.

5/87-8/87 Foreign Fisheries Observer: National  
Marine Fisheries Service, Seattle, WA.

## Selected Publications:

- Larsen, D. A., Moriyama, S., Dickey, J.T., Beckman, B.R., Swanson, P., and Dickhoff, W.W. 1997. Regulation of the pituitary-thyroid axis during smoltification of coho salmon: Quantification of TSH, TSH mRNA, and thyroid hormones. In "Proceedings of the XIII International Congress of Comparative Endocrinology" (S. Kawashima and S. Kikuyama, Eds.). p1083. Montuzzi Editore.
- Larsen, D.A., Swanson, P., Dickey, J.T., Rivier, J., and Dickhoff, W.W. (1997). *In vitro* thyrotropin (TSH) releasing activity of CRH family peptides in coho salmon, *Oncorhynchus kisutch*. *Gen. Comp. Endocrinol.* 109, 276-285.
- Moriyama, S., Swanson, P. Larsen, D.A., Miwa, S., Kawauchi, H., and Dickhoff, W.W. (1997). Salmon thyroid stimulating hormone (TSH): Isolation, characterization, and development of a radioimmunoassay. *Gen. Comp. Endocrinol.* 108, 457-471.
- Larsen, D.A. and Swanson, P. (1997). Effects of gonadectomy on plasma gonadotropins I and II in coho salmon (*Oncorhynchus kisutch*). *Gen. Comp. Endocrinol.* 108, 152-160.
- Larsen, D.A., Dickey, J.T., and Dickhoff, W.W. (1997). Quantification of salmon  $\alpha$ - and thyrotropin (TSH)  $\beta$ -subunit messenger RNA by an RNase protection assay: Regulation by thyroid hormones. *Gen. Comp. Endocrinol.* 107, 98-108..
- Dittman, A.H., Quinn, T.P., Dickhoff, W.W., and Larsen, D.A. (1994). Interactions between novel water, thyroxine and olfactory imprinting in underyearling coho salmon (*Oncorhynchus kisutch*, Walbaum). *Aquaculture and Fisheries Management.* 25:2, 157-169.
- Plisetskaya, E.M., Moon, T.W., Larsen, D.A., Foster, G.D., and Dickhoff, W.W. (1994). Liver glycogen, enzyme activities and pancreatic hormones in juvenile Atlantic salmon (*Salmo salar*) during their first summer in seawater. *Can. J. Fish. Aquat. Sci.* 51, 567-575.
- Dickhoff, W.W., Swanson, P., Larsen, D.A., and Zohar, Y. (1992). Regulation of salmonid reproduction by controlled release of gonadotropin releasing hormone analogue (GnRHa). *Am. Zool.*, 32:22A.

Brian R. Beckman

#### Education

B.S.(Biology) 1983, Oregon State  
University

M.S. (Marine Environmental Science) 1985, State University  
of New York at

Stony Brook

Ph.D. Candidate (Fisheries) 1992 - present,  
University of Washington

#### Work Experience

9/92 - present Fishery Biologist; NMFS Montlake  
Laboratory

5/87 - 9/92 Fishery Biologist, NMFS Cook Field  
Station

3/86 - 5/87 Biological Technician , NMFS Cook  
Field Station

9/83 - 6/85 Graduate Assistant, SUNY Stony Brook

#### Honors/Awards

Unit Citation ESA Petitions 1992

Outstanding Performance 1989, 1990, 1993, 1994, 1996



## Selected publications

- Beckman, B.R., W.W. Dickhoff, W.S. Zaugg, C. Sharpe, S. Hirtzel, R. Schrock, D.A. Larsen, R.D. Ewing, A. Palmisano, C.B. Schreck, C.V.W. Mahnken. 1999. Growth, smoltification, and smolt-to-adult return of spring chinook salmon (*Oncorhynchus tshawytscha*) from hatcheries on the Deschutes River, Oregon. Transactions of the American Fisheries Society (accepted).
- Beckman, B.R. and W.W. Dickhoff. 1998. Plasticity of smoltification in spring chinook salmon (*Oncorhynchus tshawytscha*): Relation to growth and insulin-like growth factor-I. J. Fish Biology 53: 808-826.
- Beckman, B.R. and W.S. Zaugg. 1988. Copper intoxication in chinook salmon (*Oncorhynchus tshawytscha*) induced by natural spring water: effects on Gill Na/K ATPase, hematocrit, and plasma glucose. Can. J. Fish Aquat. Sci., 45:1430-1435.
- Beckman, B.R. and W.S. Zaugg. 1990. Effects of Actinomycin-D on Gill Na/K ATPase activity in freshwater and seawater adapted juvenile chinook salmon. J. Fish Biology: 37:907-911.
- Zaugg W.S. and B.R. Beckman. 1990. Saltwater induced decreases in weight and length relative to seasonal ATPase changes in coho salmon (*Oncorhynchus kisutch*): a test for saltwater adaptability. Aquaculture 86:19-23.
- Beckman, B.R., Larsen, D.A., Lee-Pawlak, B. , Moriyama, S., and W.W. Dickhoff. 1998. Insulin-like growth factor-I and environmental modulation of growth during smoltification of spring chinook salmon, (*Oncorhynchus tshawytscha*). General and Comparative Endocrinology 109:325-335.
- Beckman, B.R., D.A. Larsen, B. Lee-Pawlak and W.W. Dickhoff. The Relation of fish size and growth rate to migration of spring chinook salmon smolts. North American Journal of Fisheries Management. 18:537-546.

## Section 10. Information/technology transfer

The results of the research will be published in BPA reports

and in peer-reviewed scientific journals. The investigators will continue to present results at workshops, and scientific meetings at the regional, national and international levels. For example, results of our present project were presented at the annual meeting of the American Fisheries Society (1997 -San Francisco CA; 1998 Physiology Section-Baltimore MD), the smoltification workshop (Hood River OR), chinook salmon hatchery managers workshop (Pendelton OR), natural rearing systems workshop (Port Ludlow WA), and the Pacific fish culture conference (Newport OR). Since much of the work is done at production facilities, transfer of technology is assured.